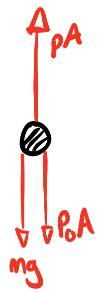
Knight: Chapter 15

Fluids & Elasticity

(Pressure in liquids, Measuring and using pressure, & Buoyancy)

Pressure in Liquids

What is the pressure at a depth *d*?



$$\Sigma F_y = 0$$

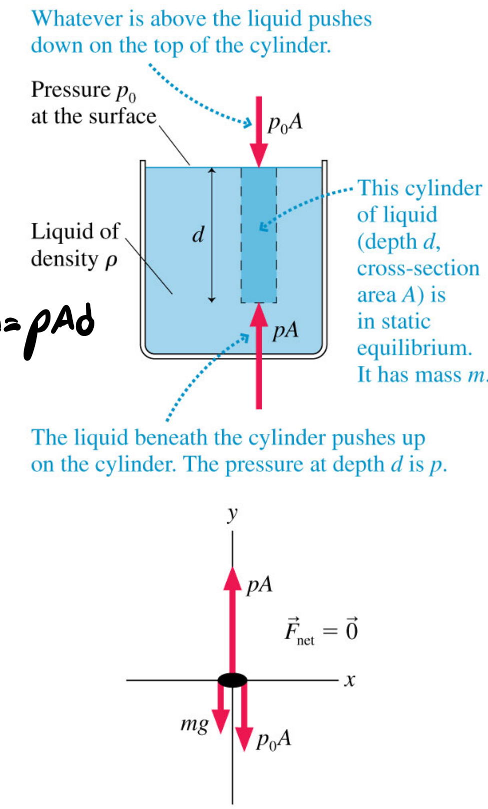
$$pA - p_0A - mg = 0$$

$$pA = p_0A + mg$$

$$pA = p_0A + \rho A d g$$

$$p = p_0 + \rho g d$$

$$m = \rho A d$$



Free-body diagram of the column of liquid

Pressure in Liquids

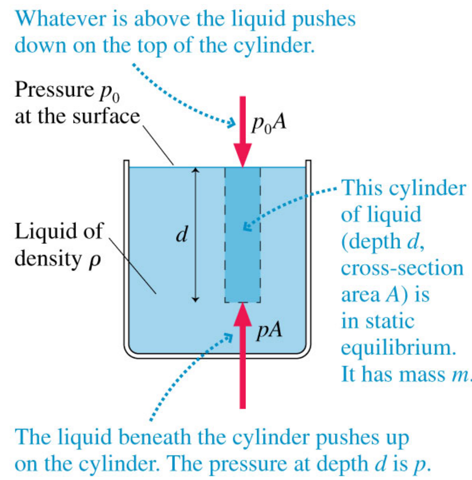
What is the pressure at a depth *d*?

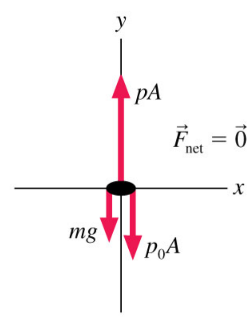
$$\boxed{p = p_0 + \rho g d}$$

- *Absolute Pressure,* p

- *Gauge Pressure,* $p - p_0 = \rho g d$

  ρ = density of fluid





Free-body diagram of the column of liquid

Pressure in Liquids

- *Force per unit area* that a liquid exerts on a submerged object

- *Depth dependent* and NOT volume dependent

  i.e. Swim *twice* as deep, then *twice* as much weight of water above you produces *twice* as much pressure on you.

- Acts equally in all directions

  i.e.: Your ears feel the same pressure under water regardless of your head's orientation.

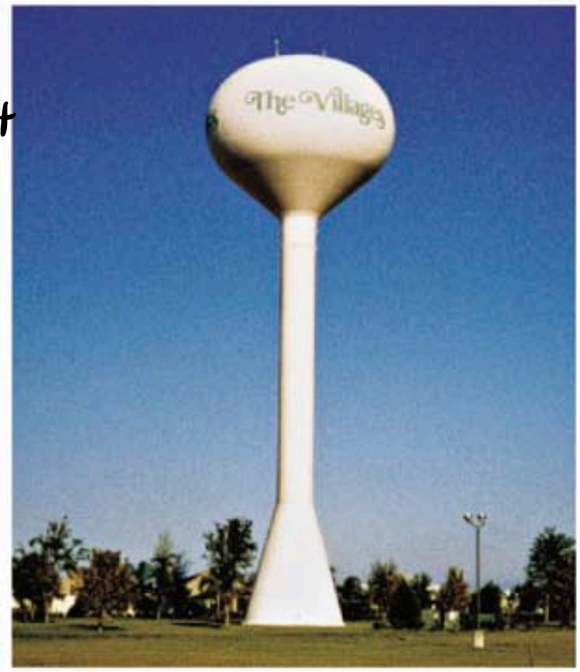
- *Independent* of shape of container:

  Regardless of the shape of a container, pressure is the same at any particular depth.

Quiz Question 1

Water pressure provided by a water tower is *greater* if the tower

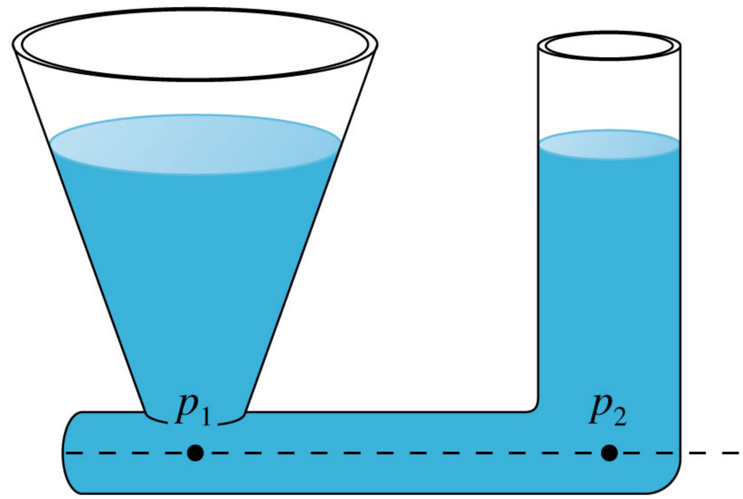
1. is taller. not volume dependent
2. holds more water.
3. Both 1. and 2.
4. None of the above.



Pressure in Liquids

- A connected liquid in *hydrostatic equilibrium* rises to the *same height* in all open regions of the container.

- The pressure is the *same* at all points on a *horizontal line* through a connected liquid in *hydrostatic equilibrium*.



Is $p_1 > p_2$?

Pressure in Liquids

$$\boxed{p = p_0 + \rho g d}$$

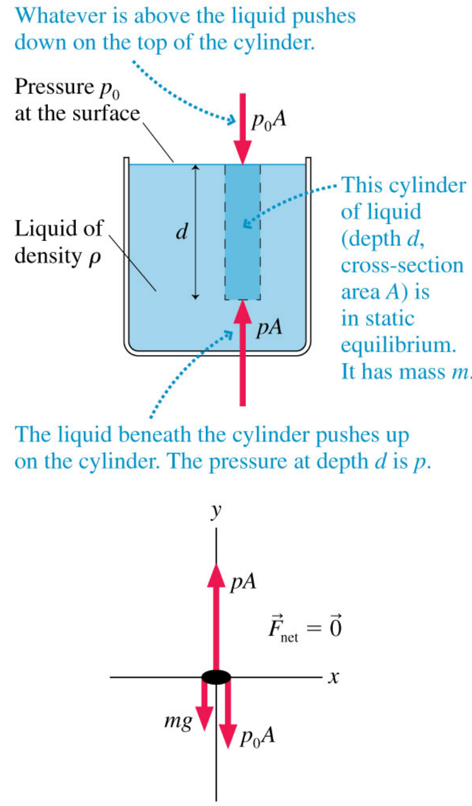
Suppose we change p_0 to p_1...

What happens to the pressure in the fluid?

$p_0 \to p_1 \ldots$

$p' = p_1 + \rho g d$

$\Delta p = p' - p = p_1 - p_0$



Free-body diagram of the column of liquid

Pascal’s Principle

A change in pressure at one point in an incompressible fluid appears undiminished at all points in the fluid.

Solving Hydrostatic Problems

TACTICS BOX 15.1 **Hydrostatics**

1. **Draw a picture.** Show open surfaces, pistons, boundaries, and other features that affect pressure. Include height and area measurements and fluid densities. Identify the points at which you need to find the pressure.
2. **Determine the pressure at surfaces.**
   - **Surface open to the air:** $p_0 = p_{atmos}$, usually 1 atm.
   - **Surface covered by a gas:** $p_0 = p_{gas}$.
   - **Closed surface:** $p = F/A$, where F is the force the surface, such as a piston, exerts on the fluid.
3. **Use horizontal lines.** Pressure in a connected fluid is the same at any point along a horizontal line.
4. **Allow for gauge pressure.** Pressure gauges read $p_g = p - 1$ atm.
5. **Use the hydrostatic pressure equation.** $p = p_0 + \rho g d$.

Exercises 4–13

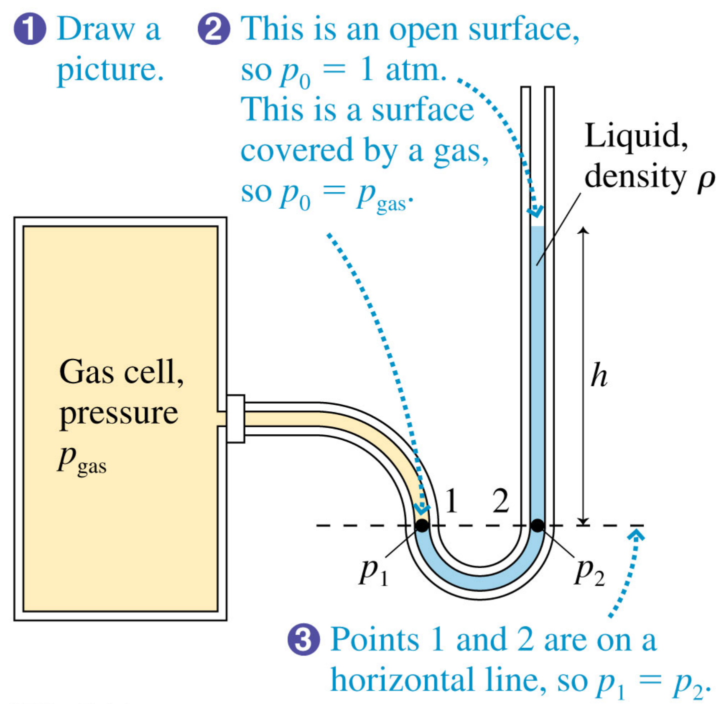
Manometers

$P_1 = P_{gas}$

$P_1 = P_2$

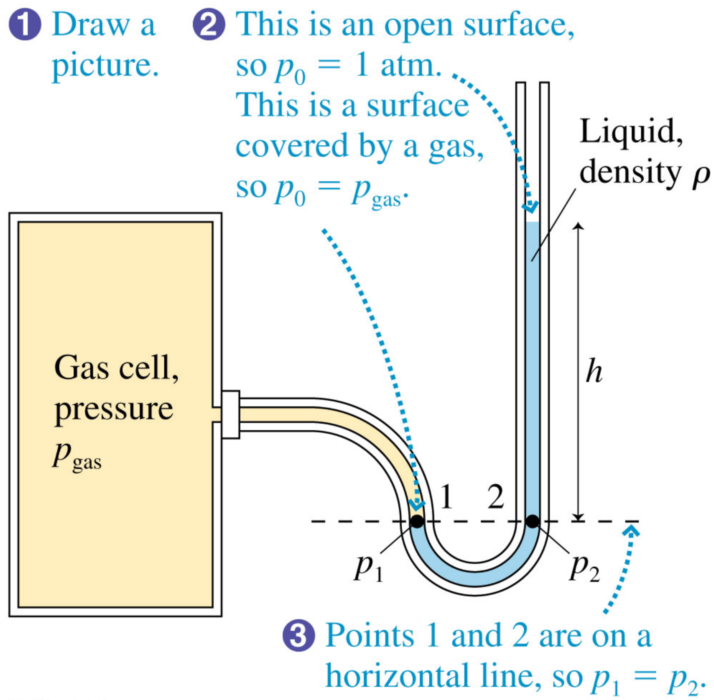
$P_2 = p_0 + \rho g h$

$P_{gas} = p_0 + \rho g h$



Manometers

$$p_{gas} = 1\ \mathrm{atm} + \rho g h$$



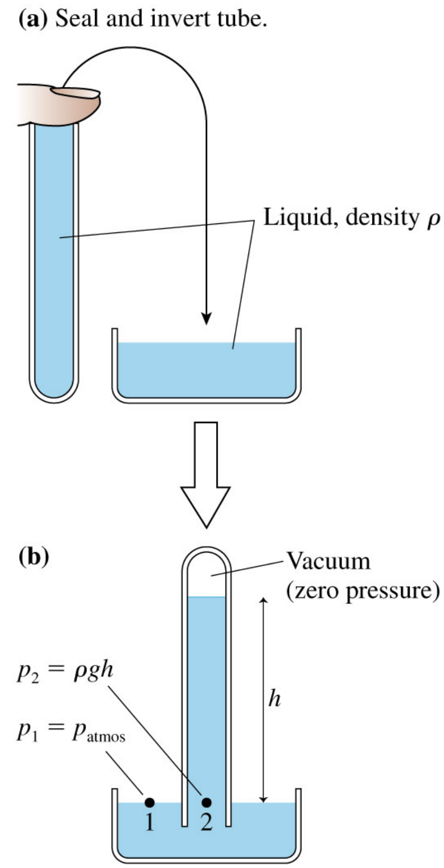
Barometers

$P_1 = P_0$

$P_1 = P_2$

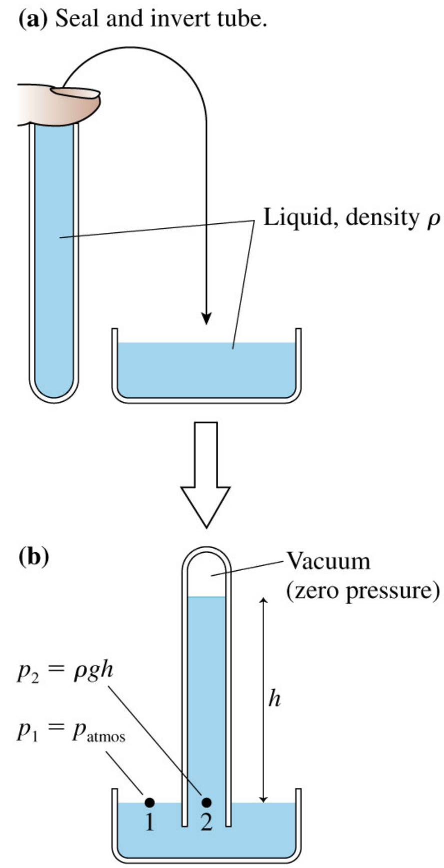
$P_2 = \rho g h$

$P_0 = \rho g h$



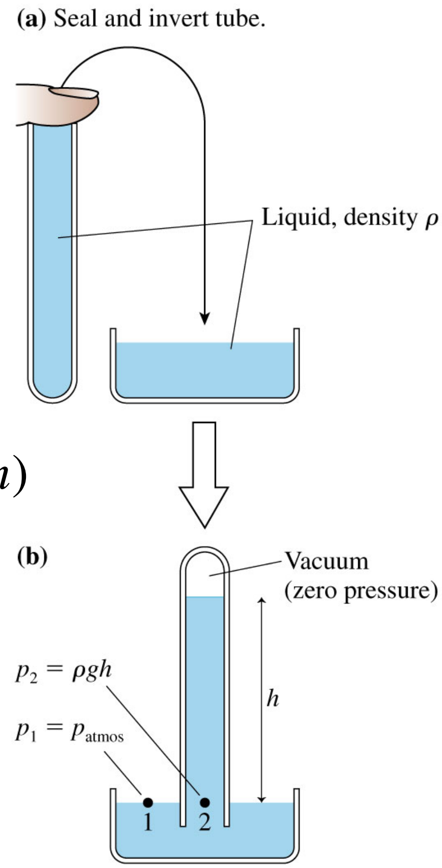
Barometers

$$\boxed{p_{atm} = \rho g h}$$



Barometers

$$\boxed{p_{atm} = \rho g h}$$



$$p_{atm} = \rho g h$$
$$= (13.595 \times 10^3 kg/m^3)(9.80665 m/s^2)(.760 m)$$
$$= 1.013 \times 10^5 Pa$$

The Hydraulic lift

How does F_2 relate to F_1?

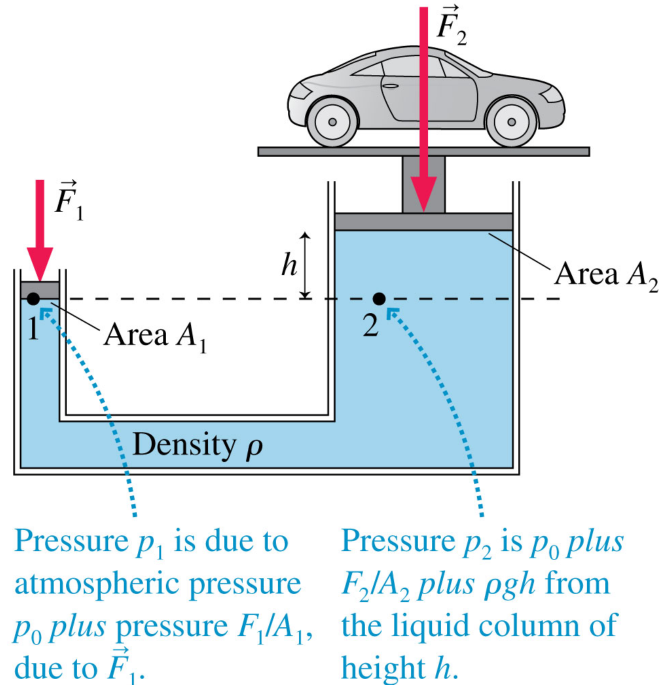
$p_1 = p_2$

$p_1 = p_0 + \frac{F_1}{A_1}$

$p_2 = p_0 + \rho g h + \frac{F_2}{A_2}$

$\cancel{p_0} + \frac{F_1}{A_1} = \cancel{p_0} + \rho g h + \frac{F_2}{A_2}$

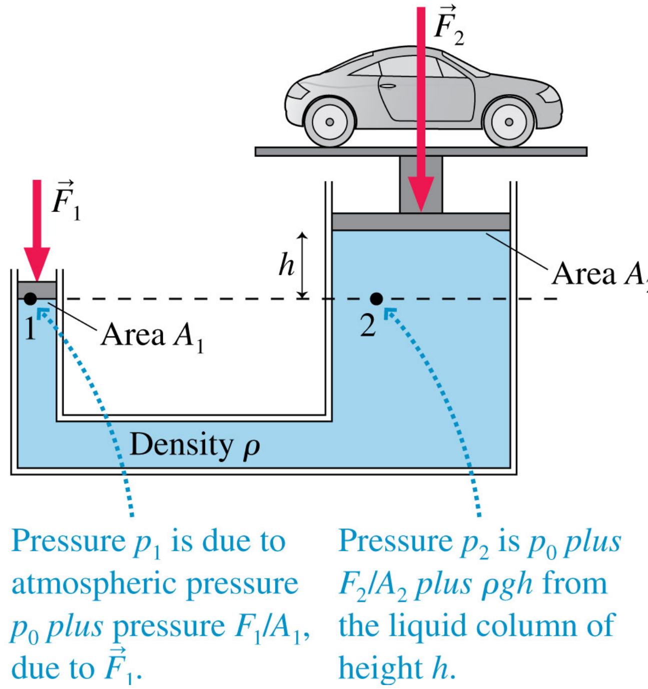
$\frac{A_2}{A_1} F_1 - \rho g h A_2 = F_2$



The Hydraulic lift

How does F_2 relate to F_1?

$$\boxed{F_2 = \frac{A_2}{A_1} F_1 - \rho g h A_2}$$



The Hydraulic lift

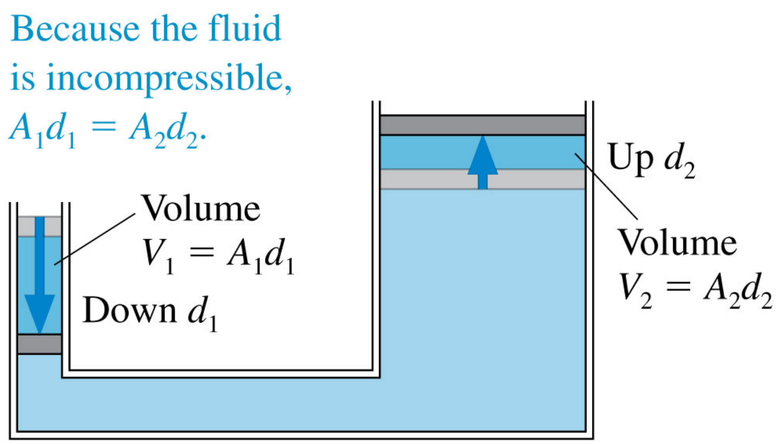
Suppose we lift the car higher…
How does d_2 relate to d_1?

$V_1 = V_2$

$A_1 d_1 = A_2 d_2$

$\frac{A_1}{A_2} d_1 = d_2$

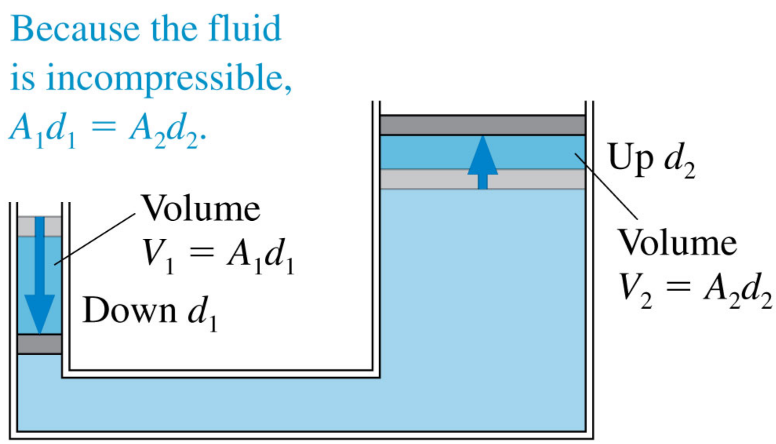
$d_2 = \frac{d_1}{A_2/A_1}$



The Hydraulic lift

Suppose we lift the car higher…
How does d_2 relate to d_1?

$$\boxed{d_2 = \frac{d_1}{A_2/A_1}}$$



Notice:
The distance is *divided* by the same factor as that by which the force is *multiplied*.

- statement of energy conservation.

i.e. 15.7: Lifting a car

The hydraulic lift at a car repair shop is filled with oil. The car rests on a 25-cm-diameter piston. To lift the car, compressed air is used to push down on a 6.0-cm-diameter piston.
What does the gauge read when a 1300 kg car is 2.0 m above the compressed-air piston?

$A_2 = \pi(0.125\,m)^2$

$A_2 = 4.9\times10^{-2}\,m^2$

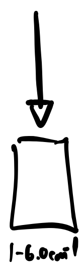
$A_1 = \pi(0.03\,m)^2$

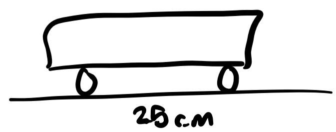
$A_1 = 2.8\times10^{-3}\,m^2$

$m = 1300\,kg$

$F_2 = mg$

$h = 2.0\,m$





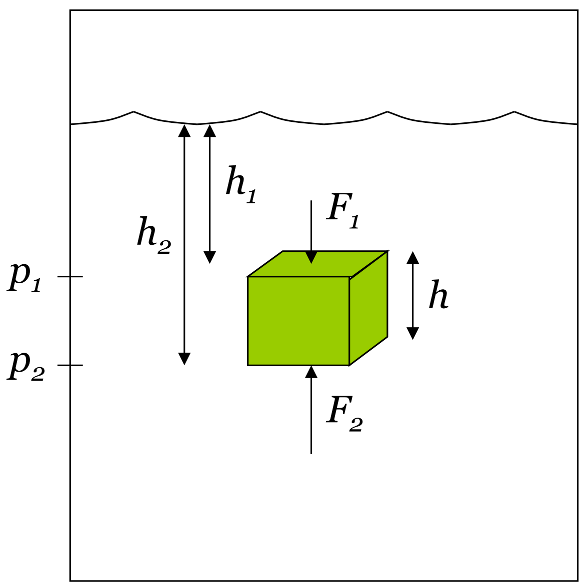
$F_1 = \frac{A_1}{A_2} F_2 + \rho g h A_1$

$F_1 = 780\,N$

$P_1 = \frac{F_1}{A_1} = 2.8\times10^{5}\,Pa$

Buoyancy

Q: Why do things feel lighter underwater
(or even float)?



Imagine a block in a fluid…

Buoyancy

The buoyant force is equal to the ***weight of the fluid displaced***.

$$\boxed{F_B = \rho_f V_f g}$$